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EFFICIENT PULSED CHEMICAL LASER

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Efficient Pulsed Chemical Laser

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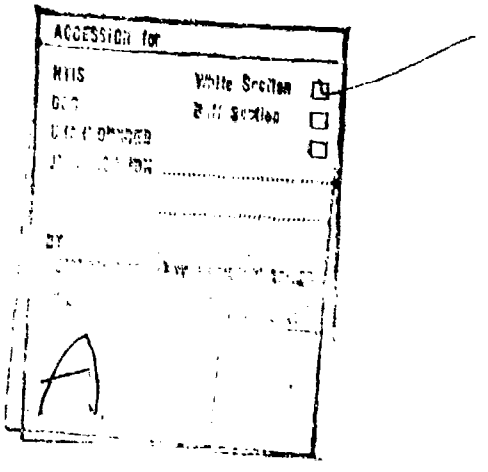

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13 ABSTRACT

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Abstract (Continued)

FOREWORD

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This report, which reflects research carried out from February through May 1972, was submitted to 2nd Lt George C. Nield, DYAE, for review and approval.

W. R. Warren, Jr., Director
Aerodynamics and Propulsion
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George C. Nield, 2nd Lt, USAF
Project Officer

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Output pulse observations are presented for a He-diluted CO_2 laser pumped by vibration-vibration (VV) energy transfer from vibrationally excited DF produced by the D_2-F_2 chain reaction. Flash photolysis of the F_2 initiated the reaction. A 290-cm^3 reaction chamber containing a 0.5-atm mixture with a mole ratio D_2:F_2:CO_2:He = 0.33:1:8:10 gave a single-pulse output energy of 2.8 J. Relative to the amount of D_2 present in the reaction chamber, this corresponds to a chemical efficiency greater than 5%.

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FIGURES

EFFICIENT PULSED CHEMICAL LASER

We have measured pulse energy and temporal and spatial distribution of the pulse from a D_2-F_2/CO_2 chemical transfer laser involving the pumping and transfer steps

$$F + D_2 \longrightarrow DF(v) + D \quad (1)$$

$$D + F_2 \longrightarrow DF(v) + F \quad (2)$$

$$DF(v) + CO_2 \longrightarrow DF(v-1) + CO_2^* \quad (3)$$

where v and * indicate vibrational excitation. The reaction was initiated by flash photolysis of the F_2.

First operation of a DF/CO_2 laser was achieved by Gross (Ref. 1), who observed the laser pulse forms obtained when various F_2O-D_2-CO_2 mixtures were flash photolyzed. Chain-reaction pumping, by the use of reactions (1) through (3), was introduced by Cool and co-workers (Refs. 2-5), who have made an extensive study of the power output of cw D_2-F_2/CO_2 lasers. After careful optimization of D_2-F_2-CO_2-He flows, they found chemical efficiencies as large as 4.6%. Several other studies of cw D_2-F_2/CO_2 lasers have also been performed (Refs. 6-8). Pulsed operation of a chain reaction D_2-F_2/CO_2 laser has been reported by Basov et al. (Refs. 9-10) and Poehler et al., (Ref. 11), who flash photolyzed D_2-F_2-CO_2 and D_2-F_2-CO_2-He mixtures, respectively. In the experiments of Poehler et al., with a total sample pressure of 700 Torr, the energy output was 5.2 J; with their composition, this corresponds to a chemical efficiency of 3.2%. Here we report preliminary studies of a pulsed D_2-F_2/CO_2 laser with flash-photolyzed D_2-F_2-CO_2-He mixtures in which pulse energies as large as 2.8 J and peak powers greater than 160 kW have been achieved. This pulse energy corresponds to a chemical efficiency greater than 5%.

Experiments were performed by the use of the apparatus shown in Fig. 1. The laser tube was a section of quartz pipe (Thermal American Fused Quartz) of 25-mm i.d. and 55-cm length fastened to aluminum fixtures holding KCl windows at the appropriate Brewster's angle. The laser tube was centered within a 1.2-m optical resonator formed by a spherical mirror of 8.8-m radius and one of a set of dielectric-coated germanium flats (Valpey). The spherical mirror was coated with Au and MgF_2 to a nominal reflectivity of 98%. The dielectric flats had various transmissivities ranging from 1 to 35%.

Helium (Matheson, 99.99%) and F_2 (Matheson, 98%) were premixed at a mole ratio of 10:1 in a 19-liter passivated stainless steel bottle at 10 atm. A flow of the He-F_2 mixture was delivered through a regulating valve to a mixer where it was injected through a calibrated sonic orifice. Metered flows of the remaining gases, D_2 (Matheson, 99.5%), CO_2 (Matheson, 99.8%), and the balance of the He were introduced into the mixer through another sonic orifice. As a precaution against preignition of the mixture, the mixer was cooled by immersion in a dry ice and alcohol bath. Likewise, downstream of the laser, the mixture flowed through a flame arrestor composed of a parallel-flow array of fine tubes that was cooled in another such bath. The flow rate was such that the 290-cm^3 volume of the quartz pipe was exchanged, nominally, every 1.5 sec. Gases from the system were exhausted by a 30-liter/min mechanical pump (Kinney) after passing through a charcoal trap to protect the pump from unreacted F_2. Pressures were measured with F_2-compatible gauges (Heise) with Cu-Be Bourdon tubes.

A Xe flash lamp of 56-cm active length (Kemlite) energized by an ignitron-triggered 14.7-μF/20-kV capacitor (Sangamo) served to initiate the reaction. Close coupling of the flashlamp to the laser tube was accomplished by wrapping the two together with an aluminum foil reflector.

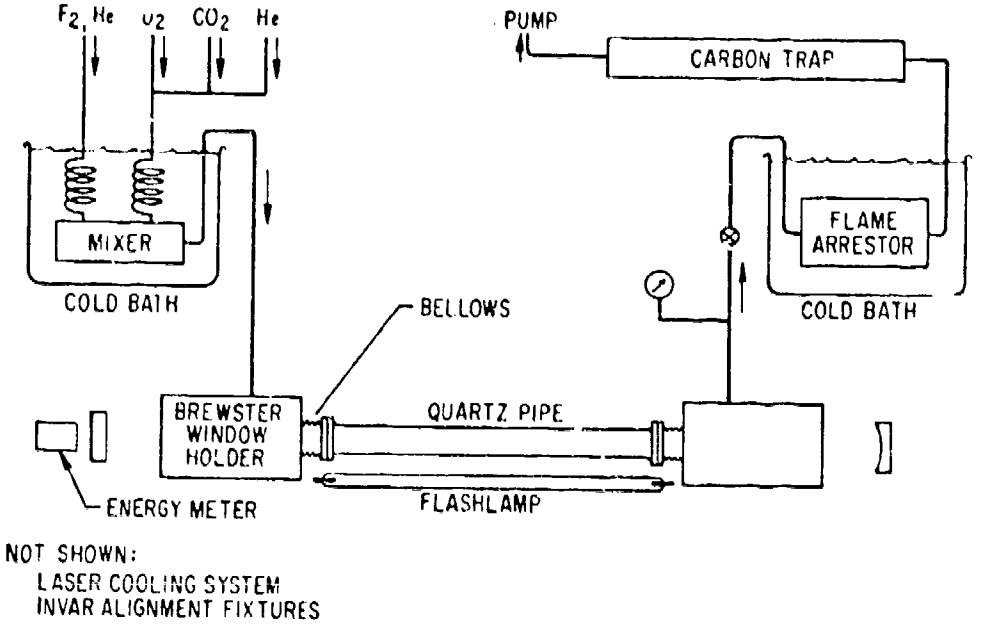

Fig. 1. High-Pressure Flash Photolysis Laser Apparatus. (The laser cooling system and In var alignment fixtures are not shown.)

The energy of the laser pulse was measured by focusing the output beam into a calorimeter. A cone-thermopile unit (TRG) with a 2-cm-diam aperture was used. The time history of the laser pulse was observed with a Au:Ge detector (Raytheon). The flashlamp intensity history was monitored with a type 929 photodiode (RCA). Estimates of the spatial distribution of energy in the laser output were obtained by observing color patterns formed in an encapsulated liquid crystal screen (National Cash Register) held in the output beam.

We have operated the laser with good success at initial pressures up to 0.5 atm. An oscilloscope record of flashlamp intensity (upper beam) and laser output (lower beam) for a 0.5-atm mixture with a mole ratio D_2:F_2:CO_2:He = 0.33:1:8:10, flash energy of 2400 J (18 kV), and 35% output coupling is shown in Fig. 2. An energy output of 2.8 J was obtained for these conditions. The liquid-crystal observations indicated that roughly one-third of the reactor cross-sectional area was filled with strong emission.

For the total volume of the reactor, 290 cm^3, and an initial pressure of D_2, 6.5 Torr, reactions (1) and (2) liberate 54.7 J. The measured laser output, 2.8 J, is 5.1% of this chemical energy release. With the actual volume usefully employed by the resonator modes accounted for an efficiency of 15.3% is yielded. This chemical efficiency is significantly larger than the 3.2% obtained in earlier chain-reaction D_2-F_2/CO_2 pulsed-laser experiments and the 4.6% value reported for an optimized cw laser.

The ratio of our laser's output energy to its volume is just slightly less than 20 J/liter atm. Again, with the active volume of the laser usefully employed by the resonator modes accounted for, an energy density of approximately 40 J/liter atm is yielded. This energy is

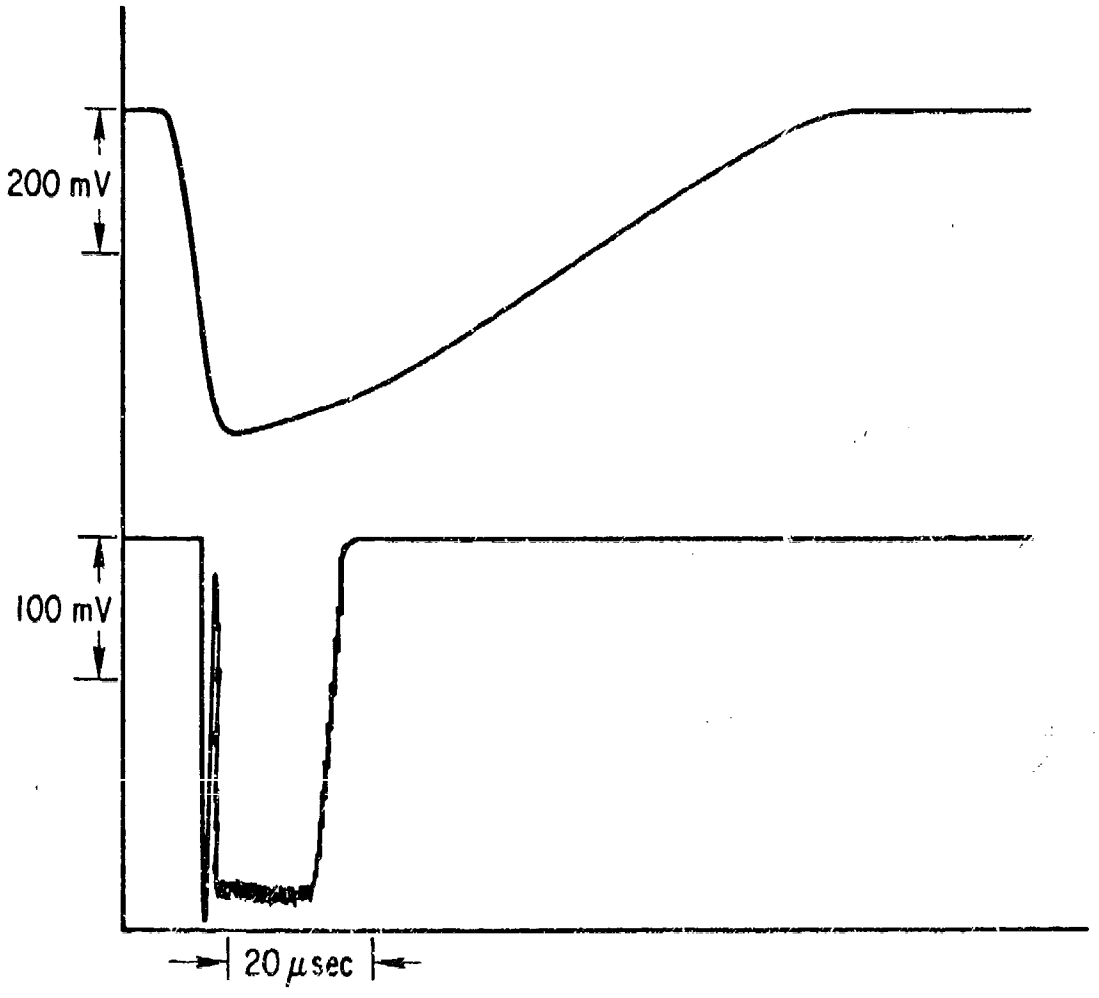

Fig. 2. Laser and Flashlamp Temporal Distribution. (a) Flashlamp Profile (RCA 929 Photodiode, 50-Ω Load). (b) D_2-F_2/CO_2 Laser Output (Au:Ge Detector, 50-Ω Load).

promisingly close to the 10- to 50-J/liter atm values reported recently for electrically pumped atmospheric-pressure CO_2 lasers (Refs. 12-14).*

Etching of the KCl Brewster windows by the corrosive gases in the system complicated the experiments. The largest energies were seen with freshly installed windows. On successive shots, window etching produced a fairly rapid deterioration in performance. We found that a BaF_2 coating on the windows gives only a moderate amelioration of this problem. Because of this complication, we have not completed a full optimization of operating parameters for maximum energy output. Thus, while the foregoing 2.8 J is the largest energy the laser has produced so far, we do not believe it represents maximum output for this device. Increased initial pressure and further optimization of mixture composition, mirror alignment, output coupling, and strength of initiation all merit attention. Exploration of these possibilities is underway, as is comparision of the results with theoretical modeling.**

*N. G. Basov, 7th Quantum Electronics Conference, Montreal, Canada, 1972.

**R. L. Kerber, N. Cohen, and G. Emanuel, "A Kinetic Model and Computer Simulation for a Pulsed DF/CO_2 Chemical Transfer Laser," (unpublished).

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